DRAFT

WORKPLAN FOR "WEEKEND EFFECT" RESEARCH

For Discussion at June 23, 1999 Workshop
{Comments Requested by July 15, 1999}

SUMMARY

The staff of the California Air Resources Board (ARB) are in the middle of a short-term (1 year) effort to use existing data to understand the causes and control strategy implications of the "weekend effect", the phenomenon of elevated ozone concentrations on weekend days in some air basins (e.g., South Coast, San Francisco Bay Area) of California. Analyses to date for the South Coast, San Francisco Bay Area, and Sacramento have reached several conclusions: (1) long-term ozone trends show that concentrations are declining for all sites for all days of the week, (2) the ozone control program is less effective on weekends (especially Sundays) in the South Coast and San Francisco Bay Area, (3) there is no weekend effect for ozone in Sacramento, and (4) particulate matter concentrations are higher during the weekdays in the South Coast. Four hypotheses are proposed to explain both the weekend effect for ozone and long-term ozone trends. The hypotheses have different control implications and are being tested by the research tasks described in this workplan. With the limited testing to date, none of the four major hypotheses have been eliminated. The only hypothesis with unambiguous supporting evidence is that Friday and Saturday night ozone and ozone precursors appear to carryover to the following morning.

The short-term effort relies primarily on statistical analysis of air quality data, and preliminary indications are that it is unlikely to result in definitive conclusions because of the limitations in the hydrocarbon database. There is a clear research need to develop accurate, gridded, speciated, day-of-week emission inventories for passenger cars, heavy-duty truck, and at least a dozen other sources over the long-term (2 to 3 years) before air quality modeling should be conducted to simulate the weekend effect.

I. INTRODUCTION

Several studies in the past decade have shown a weekend effect for ozone at many, though not all, monitoring sites in the South Coast Air Basin (SoCAB) and the San Francisco Bay Area Air Basin (SFBAAB). The essence of the weekend effect is that ozone concentrations on weekend days tend to be greater than the concentrations on weekdays in these two air basins. This phenomenon coincides with presumably lower emissions of both VOCs and significantly lower NO_X on the weekend days. Extrapolating from the weekend effect, some conclude that NO_X reductions would be counterproductive as an ozone control strategy in the California. The ARB staff believes that such a conclusion is premature, because it is contradicted by the almost uniform decline in ozone levels at all sites for all days of the week in the SoCAB and the SFBAAB. In response to the ARB's directive at their November 5, 1999 hearing, the staff has undertaken research to explain the weekend effect. The objectives of the research described in this workplan are to:

- Understand the causes of the "weekend effect" on ozone.
- Explore the relationship between particulate matter (PM) and day of the week.
- Examine the implications of such effects on pollutant mitigation strategies.

Assuming that meteorology is invariant with day of the week, the fact that human activity patterns are different on different days of the week is the only reasonable explanation for the weekend effect. However, incomplete knowledge of these changing activity patterns is only a partial explanation of our inability to state the cause of the weekend effect with certainty. Pollutants are emitted at different times and locations, and subject to the effects of meteorology (e.g., dispersion, dilution, deposition) and photochemistry to generate ozone and particulate matter. To achieve our objectives, the temporal and spatial patterns of emission activity, the overall emission inventory, meteorology, and photochemistry will need to be woven together. Accordingly, the tasks in the workplan call for an interdisciplinary approach to design and execution. The following four hypotheses of the cause of the weekend effect for ozone serve to illustrate the interdisciplinary nature of the weekend effect.

1. "NO_X-Disbenefit" Hypothesis

   During the week, high levels of NO_X emissions from heavy-duty trucks [inventory] scavenge ozone [photochemistry]. In addition, directly emitted particulate matter from trucks [inventory] absorb some of the ultraviolet radiation necessary for production of ozone [photochemistry]. Heavy-duty truck traffic is reduced on weekends in comparison to weekdays [activity]. The lower NO_X and particulate matter emissions [inventory] on weekends result in higher ozone [photochemistry].

2. "NO_X-Limitation" Hypothesis

   During the weekend, the emissions from passenger cars [inventory] are similar to those on weekends, but they are later in the day and further downwind [activity]. Heavy-duty truck traffic is reduced on weekends in comparison to weekdays [activity]. The lower NO_X levels on weekend mornings allow hydroxyl radicals to form at a faster rate [photochemistry], making the NO_X emissions later in the day and further downwind [inventory] more effective at producing ozone [photochemistry]. Weekend ozone formation is NO_X limited in comparison to weekdays, and weekend ozone levels have decreased to a lesser extent because the ozone control program has resulted in greater VOC emission reductions [inventory].

3. "Overnight Carryover" Hypothesis

   On Friday and Saturday evenings, increased passenger car traffic [activity] inject more VOC and NO_X emissions [inventory] into the nighttime boundary layer. These emissions carryover to the next morning [meteorology] when they enhance ozone formation [photochemistry]. Under transport conditions, NO_X is consumed at a faster rate that ozone and VOCs [photochemistry]. Weekend ozone formation is NO_X limited in comparison to weekdays, and weekend ozone levels have decreased to a lesser extent

because the ozone control program has resulted in greater VOC emission reductions [inventory].

4. "Increased Weekend Emissions" Hypothesis

On weekends, increased VOC emissions (and NO_X to a lesser extent) [inventory] from diurnal evaporatives, home maintenance (e.g., painting, lawn and garden), and recreation (e.g., motorcycles, boating, barbecues) [activity] enhance ozone formation [photochemistry]. The level of control of these sources has been less than that for passenger cars and stationary sources [inventory], and weekend ozone levels have decreased to a lesser extent.

Note that the last three hypotheses can explain the long-term ozone trend of a faster rate of progress for weekdays in comparison to weekend days in the 1990s. These four hypotheses are not necessarily mutually exclusive, as two, three, or possibly even all four may be needed to explain the weekend effect. As the research progresses, other hypotheses may be proposed. Rather than define tasks according to complicated ideas such as those above, the tasks in this plan pursue fundamental information that can be assembled flexibly to answer many alternative and complex hypotheses.

The next three sections describe recently completed, ongoing, and planned research tasks on the weekend effect by ARB staff in the areas of air quality, emission activity and inventory, and photochemical modeling. These are preliminary compilations of projects, and research being conducted by others will likely be identified at the June 23, 1999 workshop. The last section isolates different aspects of the four hypotheses and identifies the research tasks that will be used to test them.

II. AIR QUALITY ELEMENT

A. Introduction

Air quality monitoring data permit an empirical assessment of the response of ozone to day-of-week differences in emissions both in recent years and up to 20 years ago. Weekend emissions may differ from weekday emissions in quantity, quality, location, and timing. Though air quality analyses may not be able to isolate each of these effects, both general and specific analyses should help characterize the weekend effect and offer clues to possible mechanisms.

The first four tasks quantify the weekend effect for the SoCAB, the SFBAAB, and the Sacramento Valley Air Basin (SVAB). These air basins were selected because they have some of the highest pollutant levels observed in California and have been the object of previous analyses. Air quality data analyses in other regions of California may be carried out as time and resources allow. The remaining six tasks focus on the SoCAB for three reasons: (1) a strong weekend effect, (2) the greatest amount of routine (e.g., PAMS) and special study [i.e., 1997 Southern California Ozone Study-NARSTO (SCOS97-NARSTO)] data available in California, (3) and high ozone, PM, and precursor levels necessary for robust statistics.

B. Tasks

AQ-1. Characterize the weekend effect for ozone in the SoCAB, SFBAAB, and SVAB.

Although several studies have been performed in the past decade, the more robust statistical methods employed here provided greater accuracy and precision. Two different time periods (before and after introduction of California reformulated gasoline) were considered to verify an observation of Joe Cassmassi of systematic trends in the weekend effect in the SoCAB.

Approach:

- Analyze daily peak ozone concentrations in May to October.
- Filter out trend and seasonality, explicitly accounting for serial dependency.
- Use robust statistics to reduce the effect of outliers in estimating day-to-day changes.
- Use percent changes from day to day to characterize the weekend behavior of ozone.
- Examine spatial patterns in ozone behavior among sites.

Resources: ARB/PTSD staff

Timeline: Completed February 1999. Peer-reviewed paper accepted for publication.

AQ-2. Characterize the weekend effect for high ozone days in the SoCAB, SFBAAB, and SVAB.

Bill Chameides has observed that the weekend effect is less pronounced, and even disappears, for high ozone days in different parts of the U.S. This task will initially focus on simple descriptions of high ozone. If warranted, more statistically robust analyses will be performed.

Approach:

- Identify all days with state, national, or health advisories (>150 ppb) and compute day-of-week means for the 3-year periods used in Task AQ-1.
- Determine if the day-of-week differences are statistically significant.
- If the results are promising, perform a statistical analysis similar to Task AQ-1.

Resources: ARB/PTSD staff

Timeline: Due September 1999

AQ-3. Characterize the weekend effect for particulate matter in the SoCAB, SFBAAB, and SVAB.

Few studies have considered differences in PM by day of the week. This task will initially focus on a simple descriptions of PM10 to observe whether or not a day-of-week effect exists. If warranted, more statistically robust analyses will be performed.

Approach:

- Compute day-of-week means for all SSI 24-hour-average PM10 data for the entire period of record.
- Determine if day-of-week differences are statistically significant.
- If the SSI analysis is promising, examine day-of-week differences for components of PM (i.e., fine, coarse, nitrate, sulfate, ammonium, etc.).
- Perform a statistical analysis similar to Task AQ-1 with the hourly average TEOM data.

Resources: ARB/PTSD staff

Timeline: SoCAB SSI completed June 1999. Remainder due September 1999.

AQ-4. Analyze ozone and particulate matter trends in the SoCAB, SFBAAB, and SVAB to characterize the rate of improvement on weekdays and on weekends.

Earlier analyses have suggested that the emission reduction strategy in the SoCAB has been more effective on weekdays than on weekends. The methods used in these analyses leave open some alternative explanations for their results. The objective of this task is to analyze ozone and PM trends using methods that can confirm or override the findings of the earlier analyses.

Approach:

- For ozone, compute the mean of the highest 20% of the daily max-hour concentrations (or days greater than the state or national standard) by site and by day of the week by year for 1980-98 (at least 90% complete data) in May to October (approximately the highest 10 observations per year for each day of the week).
- For TEOM PM10, compute the annual mean and the mean of the highest 20% of the daily-average concentrations (or days greater than the state standard) by site and by day of the week by year for 1987-98 (at least 90% complete data).
- Smooth with a three-year moving average.
- Identify changes in the location and timing of peak ozone.

Resources: ARB/PTSD staff

Timeline: Due September 1999

AQ-5. Catalog diurnal profiles of air quality data for the SoCAB.

The objective of this task is to prepare a comprehensive catalog of diurnal profiles for O_3, CO, NO_X, NMHC, and PM10 (May to October) by day of week for all relevant sites in the SoCAB covering the most interesting years in the last 20 identified by Task AQ-4. For example, the hourly NO_X data at Azusa will be averaged by hour of the day, by day of the week, and by year or multi-year period. The diurnal profiles for NMHC, on the other hand, might be limited to 3-hour intervals of the day because of PAMS sampling practices. This catalog will provide a resource of information to draw upon to help evaluate hypotheses concerning causes of the weekend effect.

Approach:

- Begin with SoCAB for the calendar years 1994 & 1998; expand to other years and basins as time permits.
- Possible groupings: 1980-82, 1983-85, 1986-88, 1989-91, 1992-94, and 1996-98 (or each year separately, so that varying combinations can be examined quickly).
- Include conditional analyses, such as, "diurnal profiles for days on which ozone exceeded 90 ppb" if warranted by Task AQ-2.

Resources: ARB/PTSD staff

Timeline: SoCAB (1994 & 1998) completed June 1999. Remainder due October 1999.

AQ-6. Compare local traffic data with local air quality data (ozone, ozone precursors, and particulate matter) in the SoCAB.

The air monitoring sites are not necessarily representative of emissions from neighborhood and recreational activities. The objective of this task is to characterize the representativeness of routine air quality data collected in the SoCAB by examining its relationship with detailed freeway traffic data gathered during SCOS97-NARSTO. Traffic volumes by hour on roadways near a monitor will be compared to the air quality data by hour to see if any useful relationships exist. If gridded emissions have been developed from these traffic volumes, then ambient data will be compared with the emissions as well.

Approach:

- Use traffic count data from SCOS97-NARSTO study that have been organized and summarized by UC Davis researchers.
- Select 4 or 5 diverse sites and develop diurnal traffic profiles by day of the week for each site by averaging all Mondays, all Tuesdays, etc., for the 4-month SCOS97-NARSTO data collection period.
- Compare patterns of ambient ozone and precursors with traffic and emissions.
- If results are promising, initiate a contract with UC Davis for a comprehensive analysis.

Resources: ARB/PTSD and UC Davis

Timeline: First sites due August 1999. Remainder due in 2000.

AQ-7. Analyze ozone trends and particulate matter trends at elevated sites in the SoCAB by day of the week to characterize differences in carryover.

The potential for carryover aloft of ozone and ozone precursors from one day to the next is intriguing but elusive. Sporadic observations during special studies, such as the 1987 Southern California Air Quality Study, offered glimpses of the behavior of pollutants aloft. More recently, SCOS97-NARSTO collected more substantive data using aircraft and lidar to measure ozone up to 2500 m above the ground. The SCOS97-NARSTO data show reservoirs of contaminated air approximately 1000 m thick and containing 60 to >120 ppb ozone. If carryover is proportional to the emissions the day before (especially in the evening hours), one might expect carryover to be

lowest on Monday and highest on Saturday or Sunday mornings. The objective of this task is to analyze ambient ozone, PM10, and precursor data at elevated monitoring sites to see whether a pattern of carryover can be found in relation to the day of the week.

Approach:

- Identify sites that typically encounter pollutants "aloft" during the night and early morning hours. Some of the special monitoring sites deployed during SCOS97-NARSTO may be useful in this regard.
- Consider means, ratios, and other statistics that might best characterize the magnitude of carryover.
- Prepare trends or snapshots that summarize the differences (if any) in carryover by day of the week.

Resources: ARB/PTSD or RD staff

Timeline: Due November 1999

AQ-8. Analyze surface concentrations of pollutants (ozone, ozone precursors, and particulate matter) in the SoCAB from 2 a.m. to 6 a.m. to characterize the typical "initial conditions" for ozone production at first light.

Carryover of ozone precursors and PM in the surface-based inversion layer from one day to the next is an important factor in setting the stage for ozone and PM formation processes at the surface the following day (following sunrise for ozone). The standard monitoring network should provide a large database for NO_X and a smaller database for NMHC in the hours before sunrise. The objective of this task is to characterize the early morning conditions for ozone, NO_X, and NMHC by day of the week. Expectations are that the NO_2/NO_X ratio between 2 a.m. and 6 a.m. should be higher on Saturday and Sunday compared to Monday. If so, this finding could help verify or modify emissions scenarios used in model simulations.

Approach:

- Characterize the distributions for the averages of NO, NO_2, NO_X, NMHC, NO_2/NO_X, and $NMHC/NO_X$ by day of week, by year, by site for all sites in the SoCAB.
- Means, standard deviations, and percentiles (P1, P5, P10, P20, P50, P80, P90, P95, and P99) should be adequate.
- Years may be individual years in 1980-98 or in 3-year groups as in Task AQ-5.

Resources: ARB/PTSD staff

Timeline: Due November 1999

AQ-9. Analyze the concentrations and reactivity of hydrocarbon species by day of the week in the SoCAB.

A different mix of sources on weekends may result in day-of-week differences in various hydrocarbon species, as well as a change in the overall reactivity of the mixture. The

daily and hourly profiles may indicate the relative contributions of different emission sources (using source-receptor models). Ratios of "aged" species to "fresh" species may be useful alternatives in the absence of direct measurements of carryover. There are several existing databases that can be analyzed: (1) DRI 6-week studies in 1995 and 1996 at three sites, (2) continuous PAMS data at Burbank, Banning, and Pico Rivera for recent years, and (3) SCOS97-NARSTO measurements.

Approach:

- Compute day-of-week means for weight fractions of individual hydrocarbon species and compute the average reactivity per unit hydrocarbon using the maximum incremental reactivity scale.
- Determine if day-of-week differences are statistically significant.
- If the differences are statistically significant, perform source-receptor modeling.

Resources: ARB/RD staff

Timeline: DRI (1995 & 1996) means completed June 1999. Remainder due November 1999.

AQ-10. Write a final report on the short-term effort to understand the causes and control implications of the weekend effect.

A final report is needed to identify implications of the research to date and determine the need for follow-up studies.

Approach:

- Summarize results of previous and current analyses.
- Describe the hypotheses and any that could be confirmed or rejected.
- Recommend air quality measurement, emission inventory, and modeling programs to resolve remaining issues.

Resources: ARB/PTSD and RD staff

Timeline: Due January 2000

III. EMISSION ACTIVITY AND INVENTORY ELEMENT

A. Introduction

A fundamental input for a definitive analysis of the causes of the weekend effect and its implications on control strategies is a day-specific, hour-by-hour, gridded emission inventory. Diurnal emissions for each day of the week (rather than a typical weekday and a typical weekend day) is the ultimate objective. The current inventory, which is available in gridded form, is based on an average weekday. Adjustment factors for day-of-week differences have been approximated, but measured data derived from actual field studies is limited. A number of studies have been completed recently and others are underway or planned. The following tasks identify these efforts.

B. Tasks

EI-1. Heavy-Duty Truck Ratios in the South Coast Air Basin

The objective of this project was to analyze and calculate the weekend/weekday heavy-duty truck travel ratio in the SoCAB for the 1st and 2nd quarters in 1998. This project uses the weigh-in-motion (WIM) data as a data source.

Resources: SCAQMD contract with Caltrans

Timeline: Completed April 1999

EI-2. Characterization of Heavy-Duty Vehicle Day-Specific Driving Activity During the SCOS97-NARSTO Aerosol Field Program

This contract is to accomplish the following:

- Compile the heavy-duty vehicle and automatic traffic count data (which covers a 1-week period at selected sites).
- Determine diesel vehicle weight classification and model year.
- Assess traffic flow characteristics.
- Compare with weekday activity and ambient air quality measurements.
- Explore what effect the vehicle activity, type, and model year have on measurements.
- Develop weekend day-specific activity adjustments for traffic modeling.

Specifically, the work uses Caltrans travel count data and weigh-in-motion (WIM) data to develop ratios of light-duty, medium-duty, and heavy-duty vehicles to weekday traffic estimates. These ratios are then to be applied to heavy-duty weekday activity to obtain weekend estimates.

Resources: NREL contract with UC Davis

Timeline: Due October 1999

EI-3. Heavy-Duty Vehicle Fleet Characterization for Reduction of NO_X and Particulate Matter Emissions in the South Coast Air Basin.

The objective of this project is to obtain detailed activity data (e.g., number of start and trips, vehicle miles traveled, time at idle) and usage data (e.g., area of operation) for heavy-duty vehicles (HDVs) currently operating in the SoCAB to enable the design of incentives programs to increase the percentage of HDVs with low-emitting engines operating in the SoCAB.

This project proposes to instrument 140 HDVs traveling within the SoCAB using Global Positioning System (GPS) technology. As of April 14, 1999, 20 HDVs have been successfully instrumented. The deliverables include an intra-regional truck model.

Resources: ARB/MSCD contract with Jack Faucett Associates

Timeline: Due May 2000

EI-4. Heavy-Duty Truck and Light-Duty Vehicle Information in the San Joaquin Valley

This project had two objectives: (1) develop a procedure to calculate the weekend/weekday hourly ratio for HDT travel, and (2) calculate the HDT average hourly speeds to determine if speeds change according to day of the week or hour of the day. This work is done for the San Joaquin Valley using WIM data.

Resources: ARB/PTSD contract with Caltrans

Timeline: Completed May 1996

EI-5. Heavy-Duty Truck Activity Study

The objective of this study was to collect a sample of heavy-duty truck activity data in California. The data were collected using an automated data collection device that incorporated GPS technology. The GPS approach offers advantages in this data collection because of the ability to record the actual location of the heavy-duty trucks while in operation. The truck activity data can be properly allocated to specific geographic regions such as California air basins, counties, and urban areas during data post-processing.

The project database includes samples for 140 heavy-duty trucks that accumulated nearly 87,000 vehicle miles of travel during the data collection period. All California air basins except Lake County are represented in the database. Over 8 million GPS location records are used to describe the travel activity geographically. Because of an agreement with the Mobile Source Control Division (MSCD), however, data collected in the SoCAB were very limited. Of the total VMT collected, approximately 13.5% were within the SoCAB. The limited data collection for the SoCAB makes the use of the data for this region questionable; however it should provide useful data for other parts of the state.

Resources: ARB/PTSD contract with Battelle

Timeline: Completed April 1999

EI-6. Sacramento Instrumented Vehicle Study

This study was carried out between 1996 and 1997 in the greater Sacramento area. Owner vehicles were instrumented to determine vehicle activity patterns necessary for an accurate emissions inventory. The vehicles that were instrumented came from 139 different households that had as few as one vehicle to as many as five vehicles. A total of 199 in-use vehicles were instrumented. Some 3,500 vehicle-days, representing 110,000 vehicle miles of travel and 22,000 starts, were recorded. The study included model years from 1964 to 1997. This study is unique in that it captured: (1) household usage patterns by instrumenting all

vehicles in multiple-vehicle households, (2) seasonal effects by instrumenting vehicles over many months, and (3) air conditioning usage for a subset of the vehicles.

Resources: $279,000 ARB contract with UC Riverside CE-CERT

Timeline: Completed in 1997

EI-7. SCOS97-NARSTO Emission Inventory for 2000 SIP

As part of the SCOS97-NARSTO study, a contract was let to develop adjustment factors for day-specific on-road motor vehicle emissions. The contract is in two parts: (1) UC Davis will develop adjustment factors which can be applied to baseline traffic volumes to produce hourly, day-specific volumes for 17 episode-related days, and (2) Sonoma Technology Inc. (STI) will apply these volume adjustments to an existing baseline gridded inventory to produce gridded emissions. These adjusted inventories will then be used in the UAM modeling excercise.

Because of the location of the traffic counters, the UC Davis adjustment factors only apply to freeway travel and only account for total volumes. No distinction between light-duty gasoline vehicles and heavy-duty diesel trucks is made. These distinctions are critical in the overall analysis of weekend effect. The surface streets in the SoCAB account for nearly 50% of the VMT, and truck activity varies considerably from passenger car activity.

Resources: $66,000 ARB contract with UC Davis & STI.

Timeline: UC Davis portion completed March 1999. STI portion due June 2000.

EI-8. Motor Vehicle Activity Study

This study is for a statewide light-duty vehicle activity analysis much like the travel survey conducted by Caltrans. This study will use GPS and 1000 to 2000 data loggers for instrumenting 10,000 to 20,000 vehicles.

Resources: $500,000 ARB/MSCD & RD contract

Timeline: Due June 2001

The following two projects will provide information to improve HDT emission inventory estimates, but may be useful in studying the weekend effect.

EI-9. Heavy-Duty Truck Model and VMT Estimation

The objective of this study was to develop a methodology and computer model components, which are integrated with the current Southern California Association of Governments (SCAG) Regional Travel Demand Model, to forecast HDT travel patterns, traffic

volumes, VMT, and resultant emissions for the SCAG region. The truck model includes three main components of trip generation, trip distribution, and traffic assignment for trucks. It develops forecasts for heavy-duty truck activity using truck trip generation rates developed through surveys, regional socioeconomic data, commodity flows and goods movement data, and activity at major regional special generators including intermodal transfer facilities, airports, and major seaports. The model uses a network of regional highway facilities for traffic assignment. It simultaneously assigns heavy-duty trucks and light-duty vehicles, accounting for the effects of highway characteristics and conditions on HDT route choice and operations, and conversely the effects of various categories of HDTs on highway operations and congestion. Finally, the model allocates truck VMT forecasts by truck weight category, for emission calculations.

Resources: SCAG contract with Meyer, Mohaddes Associates, Inc.

Timeline: Draft report released November 1998

EI-10. 1999 Statewide Heavy-Duty Truck Travel Model Survey Strategic Consulting & Research for Caltrans

This project is intended to develop appropriate procedures to acquire, as well as actually collect, basic 1999 inter-regional statewide heavy-duty truck travel data. Information collected from the project will be used in the development of a statewide heavy-duty truck travel forecasting model. The model will forecast inter-regional heavy-duty truck travel in California. This project encompasses 20,000 roadside surveys.

Resources: Caltrans contract with Strategic Consulting & Research

Timeline: Due June 2000

IV. PHOTOCHEMICAL MODELING ELEMENT

A. Introduction

Air quality models are used to investigate emissions scenarios that cannot be examined empirically, either because they are projected for the future or because they were not implemented in the past. Simulations of several alternative emissions scenarios are important for gaining a satisfactory understanding of the weekend effect on ozone in the SoCAB. These simulations will use emission inventories specially developed to represent weekdays and weekend days. The simulation models may also consider sensitivity analyses relating to present-day and future-day transitions into and out of weekends. Finally, simulations of future emission-reduction scenarios (not weekday-to-weekend transitions) will be crucial for input to the consideration of alternative emission-reduction strategies.

These modeling exercises will help determine whether the observed weekend effect on ozone is directly relevant when considering the effects of future NO_X reductions on all days rather than intermittent NO_X reductions such as those that occur on weekends.

B. Tasks

MD-1. Analyze recent air quality data aloft from LIDAR, airplane observations, and ozonesondes to determine the need to modify the simulation models to incorporate these features.

Aloft measurements in most areas of the state have shown the presence of high concentrations of ozone aloft. For example, LIDAR data from El Monte during SCOS97-NARSTO showed massive layers of ozone carryover on almost all days. These layers were about 1000 m thick (starting at less than 1000 m aloft) with ozone mixing ratios of 60 to >120 ppb. The objective of this task is to ensure that ozone aloft is properly reflected by the model.

Proposed Approach:

As part of their SCOS97-NARSTO modeling efforts, the ARB and the SCAQMD will be simulating regional ozone formation and fate in southern California. This work will utilize three-dimensional air quality and meteorological data collected during SCOS97-NARSTO. A key element of this work will be review of these data to ensure that the modeling simulations properly reflect the data, both as initial and boundary conditions and for assessment of model results.

Resources: ARB/PTSD and SCAQMD staff

Timeline: Initial results due early 2000

MD-2. Prepare a day-specific weekend inventory for modeling.

The objective of this task is to prepare the best possible weekend inventory to use in simulations of the weekend effect for ozone in the SoCAB.

Proposed Approach:

As part of the SCOS97-NARSTO modeling effort, a weekend episode will be simulated. Day-specific stationary source data as well as traffic count data are available for that episode.

Resources: ARB/PTSD staff

Timeline: Due June 2000

MD-3. Simulate ozone during a Friday through Monday in the South Coast Air Basin using realistic present-day emission inventories.

The objective of this task is to attempt to replicate the present-day weekend effect for ozone in the SoCAB.

Proposed Approach:

Simulate the weekend SCOS97-NARSTO episode. Compare results to a weekday simulation, i.e., the same meteorology with weekday emissions.

Resources: ARB/PTSD staff

Timeline: Due April 2000

MD-4. Simulate ozone during a Friday through Monday in the South Coast Air Basin using future emission inventories with appropriate VOC, NO_X, and CO changes on all days compared to the present.

Similar to Task MD-3, except the objective of this task is to explore future weekend effects for ozone in the SoCAB.

Proposed Approach:

Simulate the weekend SCOS97-NARSTO episode. For this effort the initial and boundary conditions will be rolled back based on emission reductions. Results will be compared to a weekday simulation.

Resources: ARB/PTSD staff

Timeline: Due June 2000

V. HYPOTHESIS TESTING

A. Introduction

The four hypotheses identified earlier are too complex for single tests (except for modeling Tasks MD-2, MD-3, and MD-4) but different aspects of each hypothesis can be isolated to facilitate testing. Four main aspects can be identified for the hypotheses:

1. Traffic activity differences that affect the amount and/or the timing of VOC, NO_X, and diesel soot on weekdays versus weekends.

2. Emission activities that predominantly occur on the weekends.

3. Influences of ozone and precursors that carryover from Friday and Saturday evening to the following morning.

4. Differences in the chemistry of ozone formation ("what happens" and "when it happens") on weekdays versus weekends.

For each of these four aspects of possible explanations of the weekend effect, specific hypotheses suitable for testing are identified below. Although more hypotheses will almost certainly be identified during the course of research on the weekend effect, the initial lists offer a

foundation for further discussion. Each individual hypotheses is linked with a specific research task or group of tasks (as described above) designed to either confirm or reject the hypothesis.

B. Hypotheses Concerning Differences in Traffic Emission Activity and Inventory

Detailed freeway traffic data from SCOS97-NARSTO should provide a reliable basis to keep or drop some of the traffic hypotheses listed below. In addition to the SCOS97-NARSTO data, air quality data may prove to be a suitable basis for assessing the traffic hypotheses. Changes in gasoline-powered traffic verses diesel-powered traffic may be inferred by assuming that CO and NMHC are dominated by gasoline exhaust and diesel exhaust will have a noticeably different effect on NO_X compared to CO or to NMHC. Inventory-based estimates of the changes in gas-powered and diesel-powered traffic will be compared (and applied where necessary) to the indications from the analysis of ambient air quality data.

If higher precision air quality data are available from some special studies, these may also be examined, although it is unlikely that special-study data alone will provide spatial and temporal coverage that is sufficient to address the hypotheses.

Traffic Hypothesis #1: The ambient monitoring network for criteria pollutants provides an accurate, representative picture of the relative emissions of CO, NMHC, and NO_X from traffic by hour by day of week.

> Will be addressed by Task AQ-6. If hourly day-of-week traffic counts from nearby sites track the air quality data, then the monitoring sites are representative of the local community. If the spatial distribution of the monitoring network matches that of the traffic volumes, then the monitoring sites are representative of basinwide traffic activity.

Traffic Hypothesis #2: Traffic activity for passenger cars (PC) and heavy-duty trucks (HDT) is the same on weekdays and on weekend days; both the quantity and the timing of emissions from motor vehicles are the same.

> Rejected by Task AQ-5 results and several emission activity studies, and will be further addressed by Task AQ-6.

Traffic Hypothesis #3: The quantity of traffic activity for passenger cars and heavy-duty trucks is the same on weekdays and on weekend days, but the traffic activity is later in the day.

> Supported for PC by Task EI-6 results, and will be further addressed by Task AQ-6. Task AQ-5 results are contradictory with lower CO and NO_X concentrations on weekend days for all hours at many sites, but higher CO concentrations at Lynwood during mid-day on weekends. Rejected for HDT by several emission studies.

Traffic Hypothesis #4: The timing of traffic activity for passenger cars and heavy-duty trucks is the same on weekdays and on weekend days, but the quantity of traffic activity is less.

Rejected for PC by Task AQ-5 results and several emission activity studies, and will be further addressed by Task AQ-6. Will be addressed for HDT by several emission studies.

Traffic Hypothesis #5: Both the quantity of traffic activity for passenger cars and heavy-duty trucks and the timing of traffic are different on weekdays compared to weekend days. Quantify these differences if possible.

Will be addressed for PC by Task AQ-6. Will be addressed for HDT by several emission studies.

Traffic Hypothesis #6: Night-time traffic activity for passenger cars and heavy-duty trucks is higher on Friday and Saturday than during the week. Thus, additional NO_X and VOC are injected into the night-time inversion layer and are available to carryover to the next day to generate ozone.

Supported for PC by Task AQ-5 and Task EI-6 results, and will be further addressed by Task AQ-6. Rejected for HDT by several emission studies.

C. Hypotheses Concerning Weekend Emission Activity and Inventory

The following sources are hypothesized to have greater activity and emissions in weekend days:

1. Diurnal evaporative emissions (due to use of single car in multiple-car households).
2. Increased sports utility vehicle usage.
3. More gasoline dispensed on Fridays and associated increases in refinery activity.
4. Increased power generation for home air conditioning and other usage.
5. House painting.
6. Solvents used for working on cars and cleaning tools.
7. Lawnmowing and other lawn and garden activities with associated gasoline spillage and evaporation.
8. Biogenic hydrocarbon emissions from mowing lawns and pruning.
9. Motorcycles.
10. Motor boats and jet skis.
11. Private airplanes.
12. Barbecues and charcoal starter fluids.
13. Fast food preparation.

Many of these sources primarily emit VOCs, so an examination of the NMHC to NO_X ratio and NMHC speciation in Task AQ-9 may prove useful, although the results will be clouded by the decrease in diesel-powered truck traffic. It is not clear how many hypotheses are being addressed with ongoing and planned emission inventory development activities, so this area appears to be the greatest unfulfilled research need.

D. Hypotheses Concerning the Influence of Carryover of Ozone and Precursors

Results from Task AQ-5 show that new ozone is created in the hours immediately following sunrise. On weekdays, this new ozone is scavenged, but less so on Saturday and Sunday. Where did the emissions come from that generated this new ozone? On weekdays, the emissions load is dominated by fresh emissions from the morning commute. On Sundays, however, the emissions load may be dominated by emissions remaining from the preceding evening. On Saturdays, the mix is probably between the weekday and the weekend scenarios.

SCOS97-NARSTO data show that carryover of ozone and precursors aloft can be substantial (60 to >120 ppb in a layer 1000 m thick starting at 300 m above the surface). Although the ozone below 300 m is scavenged, presumably the precursors are still around. The SCOS97-NARSTO data also show that new ozone is created photochemically in the thick perched layer in the hours following sunrise. On Saturdays, this ozone is presumably formed from precursors emitted during the high-weekday-emissions regime the day before. How does this ozone carried over from Friday affect Saturday? Does it simply add to the ozone that is not titrated? Does it accelerate the chemistry of ozone formation and lead to a higher peak ozone than would otherwise develop?

Carryover Hypothesis #1: Carryover of both ozone and precursors is negligible (less than 10 ppb) on all days of the week equally.

Rejected by Task AQ-5 results and will be further addressed by Task AQ-8.

Carryover Hypothesis #2: Carryover of ozone can be significant (more than 10 ppb) but carryover of precursors is negligible on all days of the week equally.

Rejected by Task AQ-5 results and will be further addressed by Task AQ-8.

Carryover Hypothesis #3: Carryover of both ozone and precursors can be significant (more than 10 ppb) on all days of the week equally.

Rejected by Task AQ-5 results and will be further addressed by Task AQ-8.

Carryover Hypothesis #4: Carryover of both ozone and precursors is more significant from Friday to Saturday and Saturday to Sunday than on the other days of the week.

Supported by Task AQ-5 results and will be further addressed by Task AQ-8.

Carryover Hypothesis #5: The influence of carryover of both ozone and precursors aloft is the reason that peak ozone is greater on Saturday than Friday and greater on Sunday than Saturday. The boundary and initial conditions established by the day with higher emissions strongly alters the ozone produced and/or retained on the day with lower emissions.

Will be addressed by Tasks AQ-7 and MD-1.

Carryover Hypothesis #6: Carryover of both ozone and precursors near the ground is the reason that peak ozone is greater on Saturday than Friday and greater on Sunday than Saturday. The boundary conditions aloft are not influential but the initial conditions at the surface are very influential.

Will be addressed by Tasks AQ-7, AQ-8, and MD-1.

E. Hypotheses Concerning the Chemistry of Ozone Formation

Chemistry Hypothesis #1: Lower NO_X concentrations on weekend mornings result in reduced ozone scavenging and more ozone (i.e., the environment is "VOC-limited").

Supported by Task AQ-5 results of lower NO_X and higher O_3 concentrations on weekends for all daytime hours at most sites. Need to examine oxidant (i.e., O3 + NO_2) concentrations to confirm they are similar on weekends and weekdays.

Chemistry Hypothesis #2: Lower NO_X concentrations on weekend mornings result in reduced ozone scavenging allowing hydroxyl and other radicals to build up. Later NO_X emissions are more efficient in producing ozone (i.e., the environment is "NO_X-limited").

Will be partially addressed by Tasks AQ-5 and AQ-9, but difficult to test. Supported by preliminary indication in Task AQ-9 that rate of consumption of hydrocarbons is greater on weekend afternoons (presumably due to higher radical levels). Need to examine oxidant (i.e., O_3 + NO_2) concentrations) to confirm that they are higher on weekends than weekdays.

Chemistry Hypothesis #3: Diesel soot is vastly reduced on the weekends so more radiation is available to drive the photolysis reactions and increase ozone.

Rejected by Blier and Winer results that b_{scat} and solar radiation were unchanged from weekdays to weekends except for the Pico Rivera site. Data for b_{scat} at Pico Rivera were slightly lower and solar radiation were slightly more intense on weekend days than on weekdays. Will be addressed further by Harley analysis of SCOS97-NARSTO radiation data.

Chemistry Hypothesis #4: Lower NO_X concentrations on weekend mornings result in reduced ozone scavenging. This allows ozone that is carried over to remain as ozone. Similarly, the precursors that are carried over generate additional ozone at the surface and aloft in the hours of the morning when the inversion layer is being eroded. This ozone has the appearance of being "caused" by lowered NO_X.

Will be partially addressed by Tasks AQ-7, AQ-8, and MD-1, but difficult to test.